

DOSE ESTIMATES FOR THE HEAVY CONCRETE  
RATCHET WALL CONFIGURATION

### 1.0 Ratchet Wall Geometry Change

During the 1987 meeting of the APS User's Subcommittee on Conventional Facilities, we were urged to study changes in shield-wall geometry for the storage ring so as to provide an increased portion of the photon beam outside that shield. The shield-wall position, with respect to the source point, is a geometric function of the thickness of the wall, the clearance between the photon beam inside the wall (front-end area), and the corresponding clearance outside the wall. The relationship of any of these three dimensions and the resulting movement of the ratchet portion of the wall (and thus the portion of the beam line outside the shield) is about one-to-eleven, so that for each inch given up in clearance or wall thickness, eleven inches of beam-line length is exposed. Unfortunately, the two clearances were already considered minimal, and the shield-wall thickness determines the radiation dose received on the operating floor and is not really a "free parameter."

The first change made in geometry was to consider the use of heavy concrete for the wall construction. (The inner wall and roof are still considered to be normal concrete.) A thickness of 0.56 m was chosen, since that provided the same shield quality as the former 0.8-m normal concrete wall. The ratchet thickness itself was left at 0.8 m for several reasons: the wall encloses a lead/concrete plug of 0.8 m total length; there is only a one-to-one relationship between this dimension and the beam-line length exposed; and the 0.8-m length will prove to be important in consideration of the forward-angle bremsstrahlung radiation.

The changes to the clearances were made in such a way as to maintain the CDR-87 clearances only in areas where front-end devices were expected to occur. The front-end-to-wall clearance of 0.8 m was then reduced to 0.5 m, while the wall ran parallel to the next upstream beam line (outside the shield) at a 0.5-m clearance. The wall then runs parallel to the front-end at

a 0.5-m clearance until the upstream beam-line clearance is reduced to 0.2 m. At this point the outside surface of the ratchet face is placed and the above sequence is repeated with the front end beyond that ratchet face. In this way, the front-end areas retain their clearance of 0.8 m, and the initial beam-line clearance is maintained at 0.2 m. The 0.5-m clearance inside the tunnel occurs where there are no front-end components. The 0.5-m clearance outside the tunnel occurs where there is free access to the opposite side of the beam line.

The above thickness choice and geometry changes did not, however, take into account the increased radiation dose received on the outside of the shield due to the wall's closer approach to the storage-ring orbit. It is the purpose of this note to determine the resulting doses and to see if wall thickness or geometry changes are needed to provide adequate shielding for the experimental floor.

## 2.0 Ratchet Shielding Calculations

A review of the shielding estimated for the ratchet section of the storage-ring wall has been carried out. Initially, the wall shielding was computed to be 80 cm of normal concrete and the distance of closest approach was taken as 3 m, yielding a calculated dose of about 67 mrem for the case of a single point loss of the entire beam. Modification of the wall structure, relocation of the front-end components, and the substitution of high density concrete for normal concrete with an accompanying reduction in the shield thickness, have made such a review prudent. Moreover, the distance of closest approach has also become smaller, so that the possibility of an individual receiving significantly more than 100 mrem in a single dump required investigation. A third factor affecting the dose is that the corner of the ratchet nearest the positron beam orbit has been truncated in order to provide more room (see Figure 1). This has resulted in a minimum shield thickness of 56 cm of high density concrete in this region, as well as the shortest distance from an assumed point beam-loss to the dose point.

For this review, a number of beam-loss points (A, B, C, D, E, and F in the figure) at 1-m intervals in the vicinity of the ratchet-like sections of the shielding were investigated. Since the wall sections differ in the BM and ID sections, the calculations were performed for each of these sections.

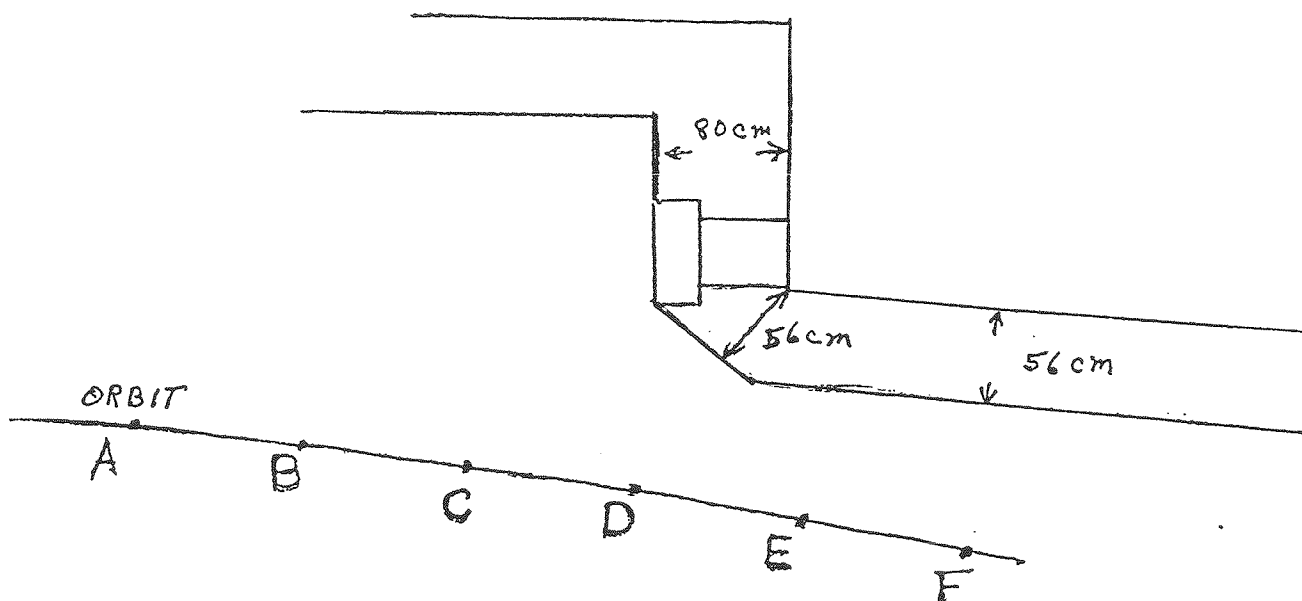


Figure 1. General ratchet-wall dimensions

The forward-directed bremsstrahlung radiation varies in intensity with the angle of emission with respect to the positron beam direction. The forward intensity for the bremsstrahlung was estimated using an expression adapted from Swanson (SWA 85). This expression is:

$$F_{H_{BREM}} = 16.7E_0(2^{-\theta_B/\theta_{1/2}}) + 833(10^{-\theta_B/21}) + 25(10^{-\theta_B/110})$$

in which  $F_{H_{BREM}}$  is in (mrem·m<sup>2</sup>/J) at 1 m,  $E_0$  is the positron energy in MeV,  $\theta_B$  is the bremsstrahlung emission angle with respect to the original positron beam direction in degrees, and  $\theta_{1/2}E_0 = 100$  MeV·deg. The first term of the expression accounts for the intense, highly-peaked, forward component of the bremsstrahlung, and the two remaining terms express the contribution as a function of  $\theta_B$ . For each of the points in the figure, a number of values for the parameter  $\theta_B$  were used to determine the dose outside the shield. If the resultant dose outside of the shielding exceeded 100 mrem, a separate calculation to determine the distance outside the shield at which the dose dropped to 100 mrem was performed.

Calculations for 7-GeV positrons were based on the assumption of 0.1 A of current in the ring and no additional local lead shielding placed around the

ring. The attenuation lengths in high-density concrete (density = 3.7 g/cm<sup>3</sup>) for bremsstrahlung (BREM), giant resonance neutrons (GRN), and high-energy neutrons (HEN) were taken as 50, 45 and 125 g/cm<sup>2</sup>, respectively. These quantities represent composite parameter values obtained from the literature (ALS 73, BAT 67, DIN 77, FAS 84 and TES 79). The dose-conversion factors for giant-resonance neutrons and high-energy neutrons are those previously used, namely 0.63 and 0.075 mrem·m<sup>2</sup>/J, respectively. The GRN and HEN components are assumed to be emitted almost isotropically, whereas the bremsstrahlung component has the angular dependence given above. The expressions for the dose contributed by each component, at the outside of the shield wall, are:

$$H_{\text{BREM}} = \frac{F_{\text{H}_{\text{BREM}}} W e^{-\frac{370(x)}{50}}}{(r + x)^2},$$

$$H_{\text{GRN}} = \frac{0.63 W e^{-\frac{370(x)}{45}}}{(r + x)^2},$$

$$H_{\text{HEN}} = \frac{0.075 W e^{-\frac{370(x)}{125}}}{(r + x)^2}$$

in which  $F_{\text{H}_{\text{BREM}}}$  is evaluated for the appropriate angle,  $W = 2.2 \times 10^{12} e^+(7000 \text{ MeV}/e^+)(1.6 \times 10^{-13} \text{ J/MeV}) = 2464 \text{ J}$ ,  $x$  (m) is the slant shield thickness for the angle  $\theta_B$ , and  $r$  is the distance from the relevant point to the inside shield wall in m.

Figures 2 and 3 show the results of the calculation, indicating the distance to the points outside of the shielding at which the dose is 100 mrem. These are shown as lines from the relevant loss point (A, B, C, D, E and F) to the dose point at the appropriate angle,  $\theta_B$ . These results were obtained by increasing the value of  $r$  in the above equations, while holding  $x$  constant, and solving iteratively for the total distance at which the dose becomes  $\leq 100$  mrem. As seen from the figures, the dose is generally  $< 100$  mrem for the majority of the situations investigated. For the few instances in which the dose exceeds 100 mrem, the distance at which the dose drops to

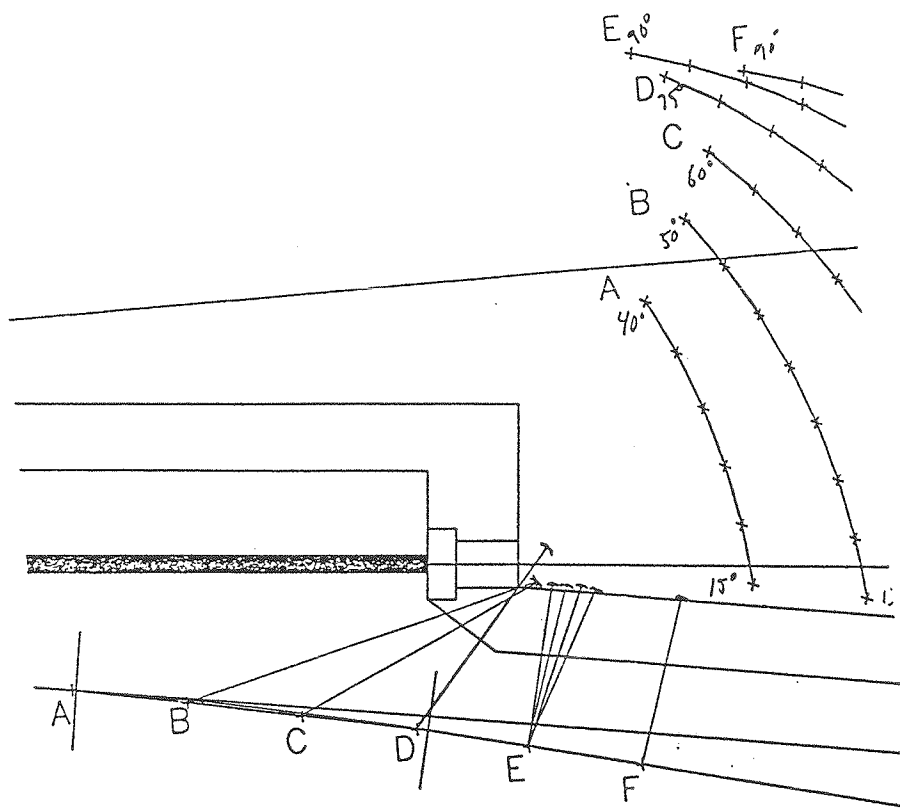


Figure 2. Section through wall in BM ratchet area.

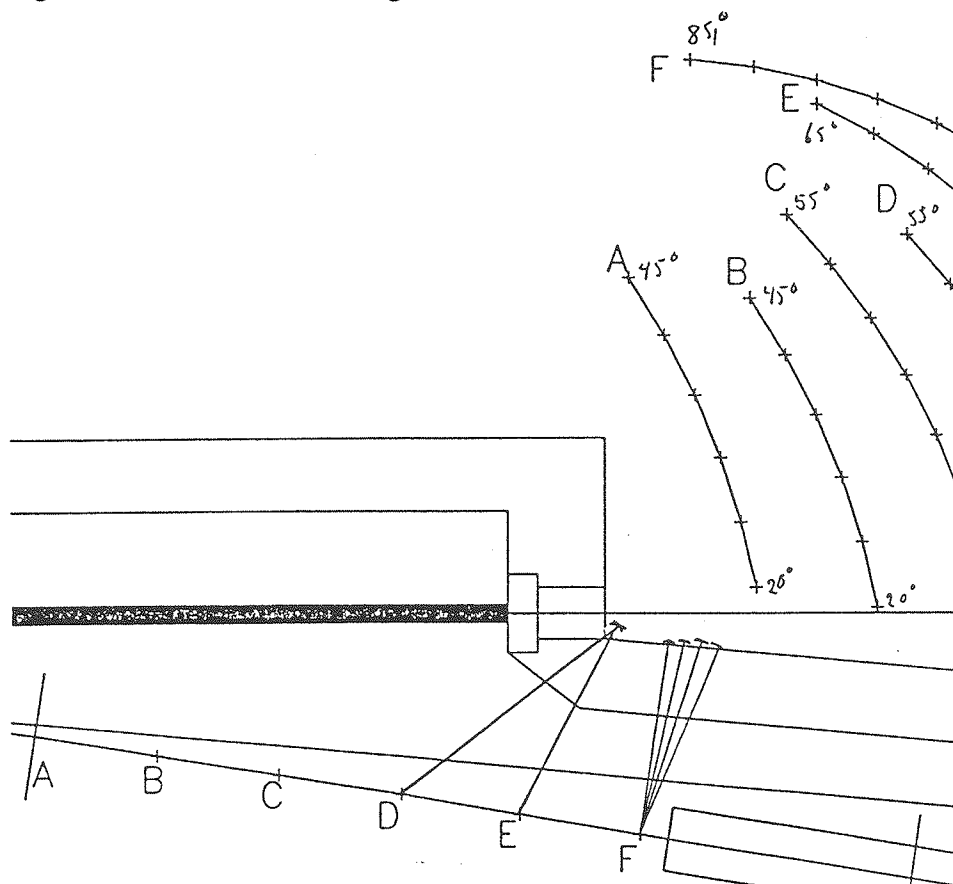


Figure 3. Section through wall in ID ratchet area.

100 mrem is generally <20 cm from the outside of the wall. One exception, as shown in Figure 2, is for a point loss at D in the figure, considering a BM ratchet face. For this case, the dose is 167 mrem on the outside of the shield and drops to 100 mrem at 44 cm from the shield. None of these conditions is deemed to represent a serious hazard potential to personnel, and no additional shielding for the operational current of 0.1 A is recommended. In addition, the setting up of exclusion zones in the areas outside of the shielding at which the dose may slightly exceed 100 mrem seems unnecessary.

Additional calculations were performed for the case in which the current is 0.3 A, and local lead shielding (7.62 cm) of the storage ring in these areas is provided. The results of these calculations indicate that with the addition of 3 inches of lead as local shielding of the storage ring, all doses outside of the shielding are reduced to below the administrative goal of 100 mrem. The highest dose rate occurring outside of the shielding under these conditions is about 81 mrem.

### 3.0 Summary

The recalculation of the estimated doses due to a beam loss at a single point in the storage-ring system indicates that the redesigned shielding geometry, using heavy concrete for the ratchet walls, is generally adequate for the parameters of no local lead shielding and an operating current of 0.1 A. For operation at 0.3 A, additional local lead shielding of 3 inches of lead will assure that all doses outside the ratchet wall shield from a beam loss at a given point will be <100 mrem.

## References

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